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Diversified Blended Teaching Innovation and Practice of Comprehensive Education—For Science and Engineering General Studies in China

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Abstract: *As an effective way to implement engineering literacy education in universities of science and engineering, general-comprehensive education has distinct features in shaping values and cultivating found talents. However, the existing traditional teaching methods, which emphasize 'teaching' rather than 'education', have posed several problems in promoting general-comprehensive course teaching in universities of science and engineering. These problems are mainly related to course teaching methods, teaching contents, teaching forms, management systems, top-level design, faculty construction, the contradiction between general and professional education, and teaching methods. With the 'Numerical Simulation of Computational Fluid Dynamics Training Course' in University of Shanghai for Science and Technology as an example, this paper investigates the teaching and learning model for developing moral, general and comprehensive courses in universities of science and engineering, and a teaching system with the main line of "Research, Preview, Discussion, Practice, Assessment" is constructed. Moreover, it performs a pathway analysis from the teaching methods, contents and forms to achieve the reform goal of establishing a solid foundation and wide caliber for general education. The general education of universities of science and engineering should take advantage of their own disciplinary characteristics and resources to build a "student-centered" multi-modal and blended curriculum system for general courses. Moreover, with online and offline teaching resources and management methods, they should integrate the concept of education into the whole process of course teaching, thus providing a reference for cultivating versatile interdisciplinary talents who can adapt to the international community.*

Keywords: *General-comprehensive education, Student-centered, Teaching model, Universities of science and engineering, Computational fluid mechanics*

1. Introduction

The 21st century is an era of knowledge and intelligence. With the rapid development of information technology and the rise of massive open online courses (MOOC), the blended teaching mode, which combines online and offline teaching, has been growing rapidly [1-2]. However, the sudden outbreak of the COVID-19 epidemic has posed a severe challenge to the traditional education system and the teaching model based on offline teaching [3]. Reinventing traditional teaching and constituting a blended approach with traditional teaching offers new possibilities for localizing global resources and creating innovative teaching and learning scenarios. Research shows that blended teaching provides students with more flexible and personalized learning experiences and allows lecturer to enrich the teaching content with new technologies and approaches [4-6].

In modern universities, professional education is higher education that prepares students with the knowledge and skills needed to work in a particular area, while general education focuses more on students' comprehensive development and is a form of holistic education. Professional education and general education are complementary rather than parallel [7-8]. However, in most universities, professional

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education and general education are two independent systems, and there are very few general courses that involve multiple disciplines or are integrated with the majors [9]. Therefore, it is necessary to accelerate the reform and innovation of engineering education, facilitate the reform of establishing a solid foundation and wide caliber for general education, as well as offer general-comprehensive courses for universities of science and engineering [10].

General education is aimed at cultivating high-quality compound talents with sound personalities. However, there are imperfect teaching and management mechanisms, inadequate top-level design of the curriculum system, inefficient faculty members, and poor coordination with professional courses [11]. All these problems are the bottlenecks in teaching general courses in universities of science and engineering. In addition, general courses are increasing while there are relatively fewer faculty members. At present, general courses are mainly taught in large classes, so classroom teaching has great limitations and is not conducive to improving students' creative capabilities [12]. Therefore, it has become a trend for general courses to develop student-centered multi-modal and blended teaching models instead of the traditional lecturing-centered and passive teaching in large offline classes, allowing students to become truly involved in the teaching process [13-14].

Computational Fluid Dynamics (CFD), is the product of the combination of modern fluid mechanics, numerical mathematics and computer science. CFD is an interdisciplinary discipline with strong vitality, and it also keeps pace with the development of society and is updated rapidly. It overcomes the shortcomings of experimental measurement and theoretical analysis, with the advantages of low cost and short time, facilitating data acquisition in the flow field. It has been extensively used in power, chemical, environmental, mechanical, construction, aviation, aerospace and other engineering technologies, and has made new advances in design, printing, medical and other interrelated industries. For this reason, it is essential to cultivate application-oriented talents who have a solid foundation in English and are familiar with the practical operations of CFD [15].

2. Conbcept design framework

The teaching team of the *'Numerical Simulation of Computational Fluid Dynamics Training Course'* (abbreviated as *'CFD course'* in bellows) in University of Shanghai for Science and Technology (USST) designed this course around the concept of "student-centered" blended teaching integrating online and offline teaching method. The team members adapted the general-comprehensive courses to the university's reality by adopting appropriate the digital teaching platform and teaching tools (such as *'One Network Learning Smart Classroom'* in USST). The team members allocated 20%-50% of the time for online autonomous learning [16], organically combining students' online autonomous learning with offline face-to-face instruction and engaging in innovations and practices of multi-modal and blended teaching. Such a reform was designed to create a blended *'golden course'* incorporating online courses with the university's classroom teaching.

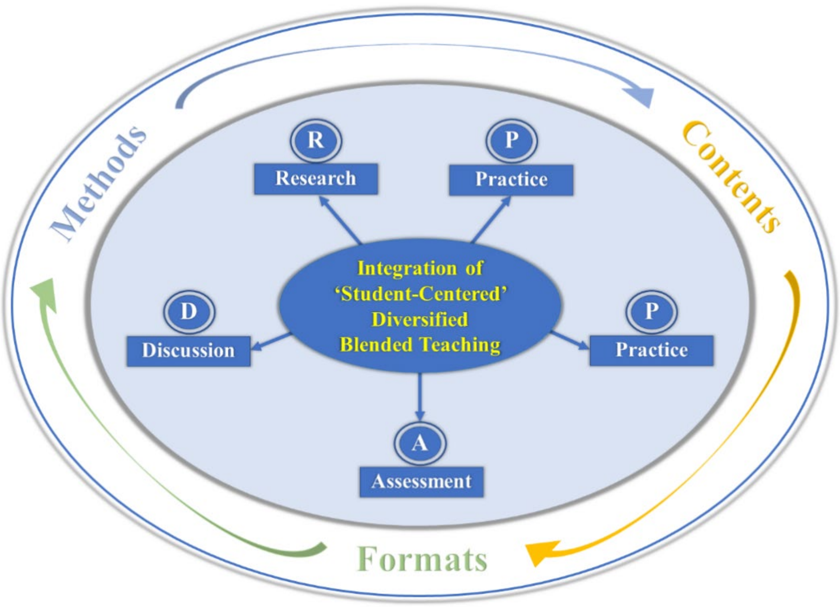

Figure 1 Course design framework of CFD course

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In this course, students were involved in all aspects of classroom teaching through innovative teaching methods, contents, and formats. Furthermore, a variety of teaching activities were conducted based on ‘research, preview, discussion, practice, assessment’ as shown in Figure 1. It aims to differentiate teaching and learning for students from different professional backgrounds and at different grades by offering ‘individualized’ teaching methods with complementary advantages. The course is taught primarily in a blended teaching mode combining online and offline, where lecturer emphasize background research and mind mapping before class, basic knowledge and case studies in class, and developing students' practical skills and teamwork after class. At the same time, all courses will be taught in English to improve students' professional competitiveness.

2.1 (Research) Preliminary research: investigation of B technology and professional application

CFD technology originated from some high-tech fields such as nuclear weapons and aerospace. With the rapid development of computers and related technology, especially the emergence of some commercial software, CFD technology is no longer a profound discipline in the tower of ivory, but has been playing an increasingly important role in various fields.

Three weeks were given after the start of the semester and before the start of the course. During this period, the students of each major were requested to conduct preliminary research. First of all, in conjunction with CFD course’s syllabus, they would learn about CFD open sources and commercial software and its development environment in their respective majors and industries. Second, they would analyze the characteristics and application scenarios of CFD numerical simulation methods for different majors.

2.2 (Preview) Preview before class: a preview of B theory and practice micro-courses

In the modern fluid mechanics research methods involving theoretical analysis, numerical computation and experimental research, CFD numerical computation complements the gaps in theories and experiments by providing an economic means to simulate real flows.

Lecturer should complete the recordings of ten micro-courses on aerospace, chemical engineering, vehicles and vessels, traditional energy, new energy, water conservancy and hydropower, agriculture, health and medical care, architecture and environment, and product design before the class, based on the distribution of majors and discipline establishment of the university. Students must complete the preview of the relevant courses, take the relevant exercises before the class, and analyze the similarities and differences of different CFD numerical simulation methods to prepare for the discussion in class.

2.3 (Discussion) In-class discussion: major-based grouping and group discussion

The contents of the course include a basic overview of computational fluid mechanics, fundamentals, an introduction to common commercial software, computational domain basics and examples, grid basics and examples, solver basics and examples, and post-processing basics and examples.

In order to enhance the interaction, communication and writing among students of different majors and to remove the barriers between disciplines, lecturer should assign students of different majors into seminar groups of about 5-8 members in classroom teaching. The seminar group members should extract the characteristic elements of different teaching modules through cooperation and communication, and prepare a report on them. Each time, one student should be selected from the group to present in the class. At the same time, lecturer should review students' presentations and broaden their knowledge.

2.4 (Practice) Post-class practice: case study and simulation practice in groups

For the four sections of computational domain basics and examples, grid basics and examples, solver basics and examples, and post-processing basics and examples, lecturer should allow students to have more space for autonomous learning and independent thinking and discussion by providing focused practice after class and by using the flipped classroom format.

According to the teaching schedule and requirements of the course, lecturer may assign students to work in groups (4-6 students/group) with similar majors, and determine the issues related to computational fluid mechanics in the scope of this course according to the group discussions. Each group should build a CFD model for a real-world problem they have chosen, and solve the model using relevant software. After that, the group members should draw conclusions, make reasonable suggestions and

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prepare a report to complete the final presentation for their group. According to the university's humanistic characteristics, history and professional characteristics, the spirit of "honesty, integrity, diligence, benevolence; learning, reflection, vision, aspiration" should be incorporated into the course design report.

2.5 (Assessment) Performance assessment: information-based assessment and personalized assessment

Lecturer should adopt 'Internet +' technology in classroom teaching to make data statistics on the whole process of student learning and accurately grasp the effectiveness of classroom teaching. They should teach students on the teaching platform *'One Network Learning Smart Classroom'* in USST, and make statistics on online attendance, interactive Q&A, class discussion, process evaluation and report assessment. According to the data analysis results, lecturer can keep abreast of students' learning points and their knowledge mastery, and adjust the teaching contents and methods in a timely manner.

In addition, students should be individually assessed and evaluated by their group members in an efficient and information-based approach. In this way, lecturer can better control and adjust the whole teaching process of CFD course classes and motivate students to engage in classroom learning, thus improving the quality of classroom teaching.

3. Pathway analysis

Compared with the original syllabus, CFD course does not only introduce the commonly used B-software but also introduces the whole CFD calculation process. It allows students to have a preliminary understanding of the commonly used 3D modeling software, meshing software, CFD commercial software and flow field post-processing software in the industry, and broadens the engineering perspective of students from various majors. Due to the features of CFD, the latest algorithms and models of CFD need to be updated in real time in order to keep the course up-to-date. How to achieve the goal is a challenge for the development of the course. Therefore, it is necessary to combine the innovations and practices in three dimensions: teaching methods, contents and formats, in order to truly build this course as a general-comprehensive course for universities of science and engineering, as shown in section 3.1-3.3.

3.1 Innovative teaching contents to enhance the attractiveness of blended teaching

3.1.1 Innovation in teaching resources

Through micro-course teaching and animation teaching, lecturer should organically integrate teaching content in online and offline classes, and pay attention to the interface between online and offline content. In online teaching activities, lecturer should arrange assignments and seminars that can accurately assess and give feedback on students' learning and quality, and provide a basis for offline course strategies. They should also have a summary, reflection and expansion of the offline content. In offline classroom teaching and interaction, lecturer must complete the testing, consolidation and transformation of students' online learning outcomes.

3.1.2 Innovation in the thinking of teaching

A sound classroom environment should be built to enable lecturer and students to work together through interactions before, during and after class. In online teaching activities, lecturer may design preview exercises, and chapter tests to facilitate the interaction between students and teaching resources. Lecturer can encourage and communicate with students through online activities such as group discussions, mutual evaluation of assignments, and online Q&A. In offline teaching activities, lecturer can enhance the communication or demonstration cycle between students and lecturer and among classmates by organizing teaching activities or with the aid of intelligent teaching tools.

3.1.3 Innovation in teaching methods

Through the multi-modal and blended teaching of 'Research, Preview, Discussion, Practice, Assessment', it not only addresses the problem of combining commonality and individuality in teaching. It also creates a symbiotic classroom involving all students and lecturer. At the beginning of the course, lecturer should fully communicate with students about the difficulties and challenges they may encounter in learning the course, and prepare students with psychological expectations. In the early stage of online

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learning, lecturer can give students reminders through online group chatting and emails. In offline lessons, lecturer should follow the principle of gradual progress. Lecturer should help students adapt to the teaching style, establish and strengthen their awareness of the teaching model, and gradually complete the transformation from primary classes to advanced classes.

3.2 Innovative teaching methods to form a multi-channel blended teaching mechanism

3.2.1 Participatory and experiential teaching

In the teaching design, lecturer should design corresponding teaching tasks according to the course modules and learning subjects, and stimulate students' curiosity by completing the tasks to cultivate and assess them in all aspects. Students may encounter various problems and obstacles in completing each task, and resolve the problems and complete the tasks through self-effort and teamwork, thus improving their professional knowledge and cultivating their sense of teamwork.

3.2.2 Activity and context-based teaching

In both in-class learning and after-class practice by majors, lecturer should guide students to practice in the field in groups and on a regular basis, based on practical applications of engineering and complemented by their interests. In this way, students can reinforce the application and understanding of CFD in their professional fields and appreciate the charm of integrating professional skills with production practice. In addition, lecturer should analyze typical cases through online and offline teaching methods, so that students can receive knowledge and internalize emotions during the practice.

3.2.3 Imitation and innovation-based teaching

Lecturer should strengthen students' ability to imitate and translate CFD technology through online and offline teaching and demonstration. In addition, students should learn from each other and stimulate their capabilities through group discussions and presentations. Lecturer should pay special attention to the differentiated cultivation of students from different majors and backgrounds during teaching. They should teach students by groups, majors, and grades to better cultivate students' innovation consciousness and practical application capabilities.

3.3 Innovative teaching formats to improve the effectiveness of blended teaching

3.3.1 Innovations in resource development

Lecturer should transition from the traditional teaching format of 'teaching first and learning later' to the online and offline blended teaching format of 'learning first and teaching later' and complete the transformation of classroom functions through online discussions and online exercises. In the teaching of this course, students no longer passively receive knowledge, but apply what they know to complete the transfer of professional knowledge.

3.3.2 Innovations in activity design

Lecturer should analyze the whole teaching process through the big data analysis function of the teaching platform and teaching tools, combining online and offline learning activities such as students' brainstorming and group collaboration. Also, they should make a summary of each lesson, and dynamically adjust the organization of teaching resources and the key and difficult points of teaching, starting from the achievement of teaching objectives, the effectiveness of teaching strategies, and the rationality of teaching design.

3.3.3 Innovations in model building

Lecturer should adopt online techniques to improve the efficiency and effectiveness of traditional teaching methods, and classify the teaching content according to the gradient of difficulty. They can ask students to practice online independently, to discuss offline in small groups and provide targeted instructions, so that students can fully and effectively practice and master what they have learned. At the same time, lecturer can continuously optimize the teaching process and guide students to improve their engineering practice skills under the guidance-feedback mechanism. They can further adjust the teaching design by providing differentiated training programs for students.

3.3.4 Innovations in learning experience

Based on full respect for the differences, lecturer should increase the proportion of regular performance both online and offline when designing the composition of the course grades, emphasizing

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the efforts and progress made by students during their learning process. The flexibility of online and offline blended teaching means that lecturer can refine student categories as much as possible, personalize their instruction, and better integrate CFD technology into the future development plans of the university.

4. Dilemmas in implementation and effective approaches

The links in the whole blended teaching process determine whether the CFD course can maximize the advantages of blended teaching in its teaching innovation and practice. These links include the teacher's teaching design, the construction of course resources, students' initiative, the variety of assessment methods, the degree of communication between lecturer and students, and the ease of use of the blended teaching platform. Problems in any one of these aspects may affect the effectiveness of teaching. In summary, four common problems affect the effectiveness of teaching, as follows:

4.1 Insufficient guidance on the design of the learning environment

Weather blended teaching can achieve the desired effect is highly related to the teacher's teaching design. According to the traditional teaching method, the whole teaching process is designed with the teacher as the dominant actor, which only extends the time and space for learning, without bringing into play the main role of students and the dominant role of the teacher. It is a renewal of the traditional teaching style, but it does not achieve the effect of blended teaching. Some lecturer asks students to preview their learning online, but still teach what is taught online in offline classes, so that what is taught online is exactly the same as what is taught offline. In this way, students may mistakenly believe that it does not matter if they do not study online, because the content they study online will also be taught in offline classes, which defeats the purpose of blended teaching.

4.2 Waiting time and efficiency

For blended teaching, an online platform is essential for online learning. The ease of use of the online teaching platform lecturer choose also affects students' engagement. An overly complex platform may affect students' experience, increase the time cost of learning, and cause students to become bored while using it, thereby affecting their learning efficiency.

4.3 Personalization and procedures

Blended teaching involves both online and offline teaching. Students should also be assessed by blending online and offline assessment methods. The online assessment should cover pre-class, in-class and after-class assessments. However, for simplicity, some lecturer only performs some of the items of online assessment, such as just signing in to class. As a result, students are likely to complete what the teacher assesses, and muddle through the rest at will, thus affecting the teaching effectiveness.

4.4 Low motivation and interest in learning

Lecturer is usually overloaded with teaching tasks and do not devote more time and energy to designing and producing teaching resources. Because of this, some lecturer only electronically processes classroom teaching resources as learning resources before, during or after class, which leads to the low interest of students and affects their engagement.

Therefore, in order to improve the above-mentioned problems in the teaching process, the university should provide policy and technical support at the macro level. At the micro level, lecturer need to improve their abilities to design and apply blended teaching. At the same time, it is necessary to increase students' engagement as the main actors. Specific measures are suggested as follows:

(1)Combining the characteristics of the CFD course and the application scenarios in the industry, lecturer should allow sufficient time and opportunities for students and provide personalized instructions to enrich the teaching design;

(2)The university may organize regular debriefings and exchanges on the implementation of blended courses, so that lecturer can learn from each other through group debriefings and exchanges, and improve and optimize their designs and implementation processes;

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(3)In addition to students' motivation for learning and their desire for knowledge, lecturer should also motivate students from various aspects, guide and supervise students properly, and offer elements of real-time assessment;

(4)The learning content should be dynamically adjusted depending on the students' online learning. The content should not be repeated, the instructions should be deepened, and the format should be diversified and vivid to attract students' attention.

5. Conclusion and future prospects

In conclusion, with the development of computers, CFD numerical simulation plays an increasingly important role in the further study and employment of students in universities of science and engineering. We should effectively establish a general-comprehensive course for all the students in the university, and actively exploit the advantages of this course. At the same time, we should establish the interconnection between the CFD course and other courses based on the characteristics of the CFD course as an interdisciplinary course. Based on this, we can create a dialogue between majors. In addition, we should remove the barriers between disciplines and unify the foundation of cultivating students' core qualities, emphasizing their comprehensive quality. In this way, students can acquire different perspectives through interdisciplinary learning and become more competitive in their core competencies based on the mastery of beneficial professional tools.

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